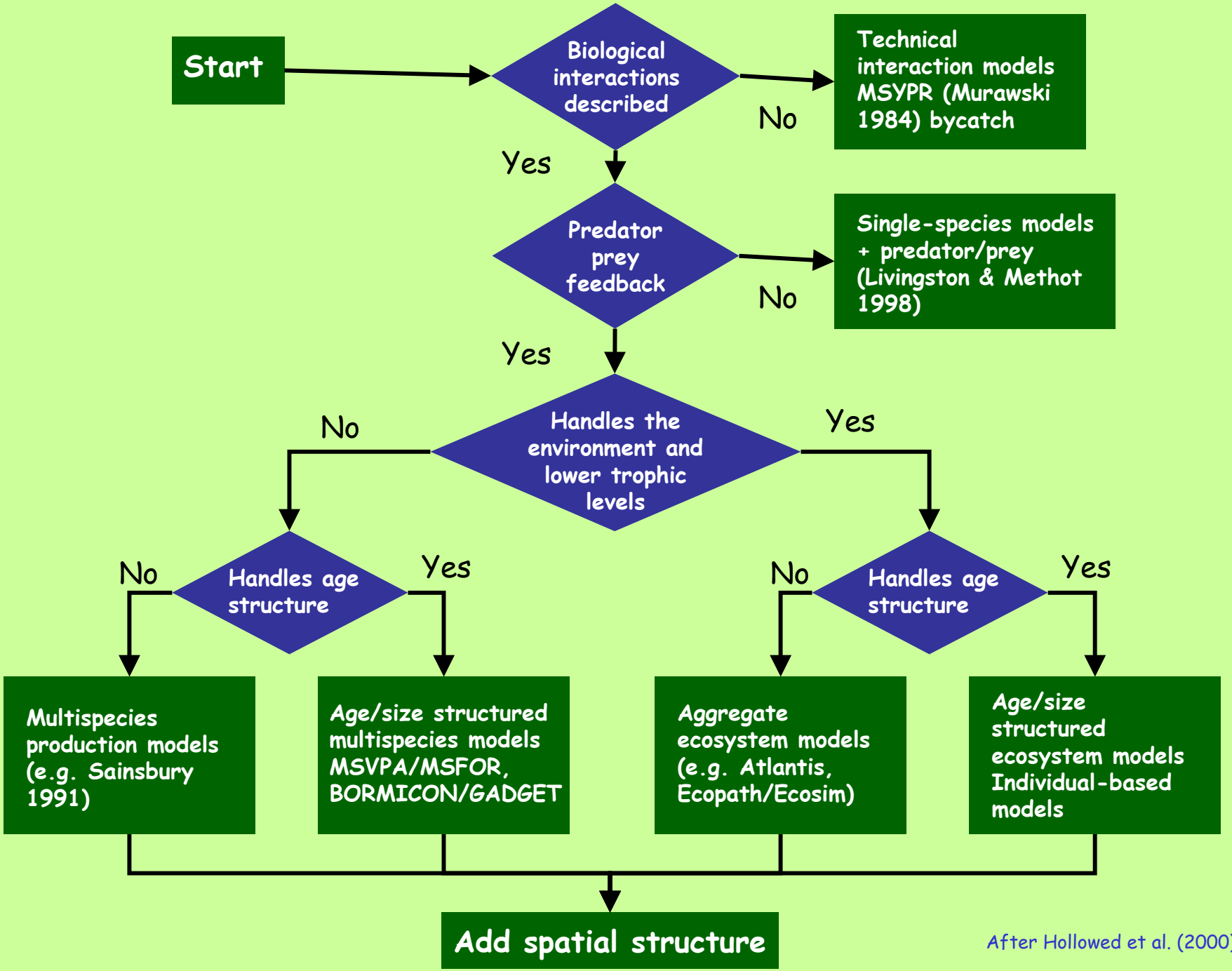
Overview of Multispecies and Ecosystem Models

For each class of models:

- What are the main properties?
- What are the data requirements?
- Is there a salient example?
- Has the model been used to provide management advice?

References: Hollowed et al. 2000. ICES J. Mar. Sci.
ICES Working Group on Ecosystem Effects of Fishing Activities

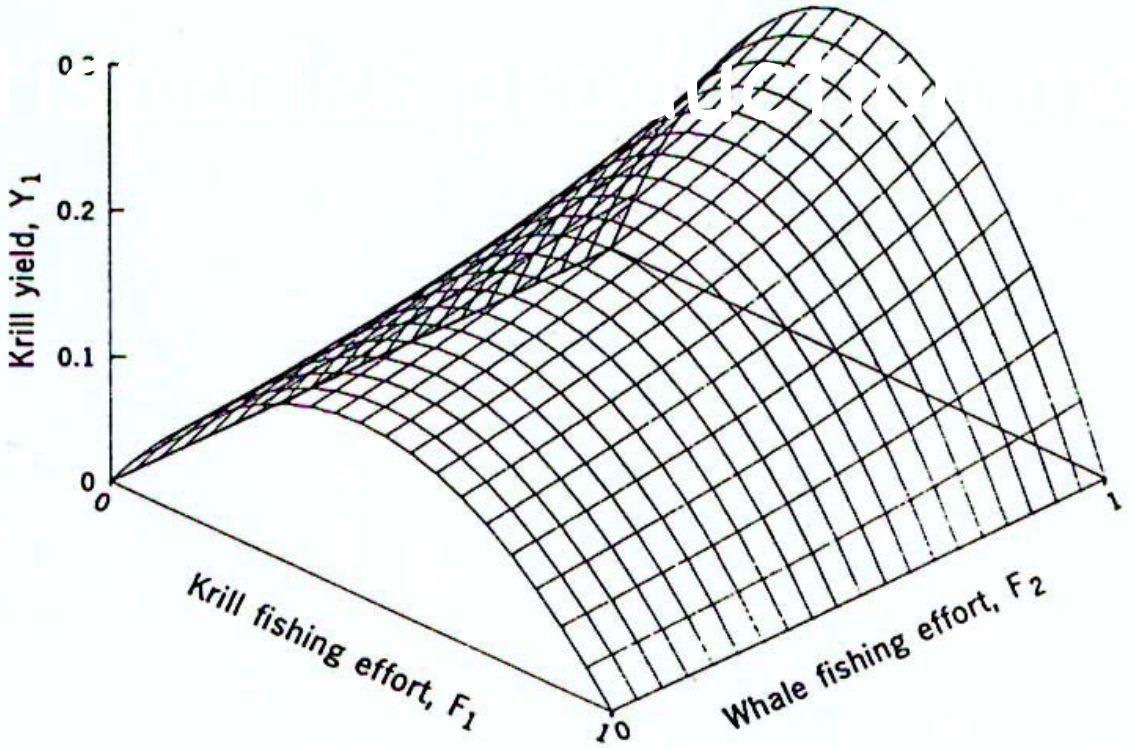


After Hollowed et al. (2000)

Single-species models with variable prey or predators

- ✓ E.g. pollock model with variable predator abundance (Livingston & Methot 1998).
- ✓ Only need to model the dynamics of the target species; interacting species are fixed.
- ✓ Can be used for stock assessment, to set biological reference points and for medium-term (5-yr) projections.
- ✖ Trophic feedback is unidirectional. Indirect trophic interactions and long-term feedback is ignored.

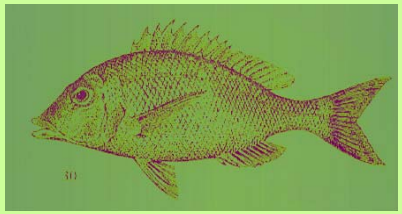
Multispecies predator models



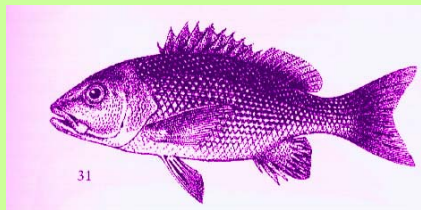
- ✓ These models have been useful for examining the trade-offs between prey and predator yields (May et al. 1979).

Multispecies production models continued…

- ✓ Biomass-dynamics models can be fit statistically to time-series of abundance or biomass data.
- ✓ They can be used to evaluate alternative hypotheses about community dynamics.
- ✓ E.g. Sainsbury (1991) constructed four possible models to explain changes in the fish community on the northwest Australian shelf.



$$B_{t+1} = B_t\left[1 + r - \frac{r}{K}B_t - \frac{\beta r}{K}W_t - F_t\right]$$



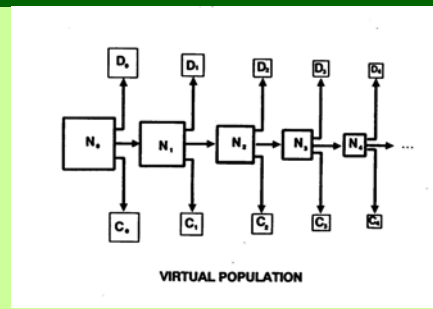
Multispecies production models concluded

- ✓ Non-linear trophic interactions and time delays in the effects of predation can give rise to multiple equilibria (Beddington et al. 1975, Basson & Fogarty 1997).
- ✓ This is one approach for modeling regime shifts (Collie et al. 2004).
- ✓ Production models can rival the predictive ability of age-structured models.
- ✘ Multispecies production models ignore size and age-dependent demographics, and the size selectivity of fishing.

Length-based models

- ✓ Many demographic processes (e.g. feeding) depend more on size than age.
- ✓ Size data are commonly available from surveys.
- ✓ Useful for animals that can't be aged.
- ✓ Can be used to calculate community metrics, such as size spectra (Bianchi et al. 2000).
- ✗ Generally used as simulation tools, not fit to multispecies data.

Dynamic age/size-structured multispecies models



- ✓ Track the fates of cohorts backward in time (MSVPA) or forward from recruitment (GADGET).
- ✓ Natural mortality is a dynamic function of predator abundance and prey availability.
- ✓ Growth can be linked to food availability, as observed in boreal ecosystems.
- ✓ Forward projections can be made to examine trade-offs between predator and prey harvests (MSFOR).
- ✖ Require age/size stratified data on abundance, catch, and diet composition.

Aggregate ecosystem models

- Derived from food webs and energy budgets.
- Species are aggregated into functional groups, especially at the lower trophic levels.
- Mass-balance models assume linear trophic interactions (e.g. ECOPATH).
- Dynamic ecosystem models are useful for simulating time dynamics under different harvest scenarios (e.g. ECOSIM).
- Aggregate ecosystem models are chronically underdetermined (Vezina et al.).

Age/size-structured ecosystem models

- Individual functional groups are generally less aggregated and their dynamics are described with greater temporal resolution.
- E.g. the European Regional Seas Ecosystem Model (ERSEM) traces carbon flows through the North Sea Ecosystem.
- Given the high level of detail, these models are often constructed as simulations and individual based models.
- Coupled biophysical models concentrate on the lower trophic levels and planktonic life stages (e.g. Batchelder and Williams 1995).

Spatial implementations

- ✓ Cellular automotons (Pascual & Levin 1999) and spatial grids (Shin & Cury 1999).
- ✓ Age-structured multispecies models (e.g. BORMICON) allow for local prey depletion.
- ✓ Aggregate ecosystem models (ECOSPACE).
- ✓ Coupled biophysical models (IBMs).
- ✓ Spatial models can be used to evaluate MPAs.
- ✖ Explicit spatial structure may be unnecessary if the time delays in prey and predator dynamics are properly described (Ellner et al. 2001).

Conclusions

- A plurality of approaches is desirable.
- Most multispecies models have a dial that corresponds to predator feeding rates.
- Turning this dial shifts the dominance between predators and prey.
- Measuring feeding rates may be more important than the model formulation.
- Simple models can be useful for decision making.
- Need also to incorporate habitat, regime shifts…